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Affordability Analysis of Lead Emission Controls for a Smelter-Refinery

JACA Corp., Fort Washington, PA

Prepared for:

Environmental Protection Agency, Research Triangle Park, NC

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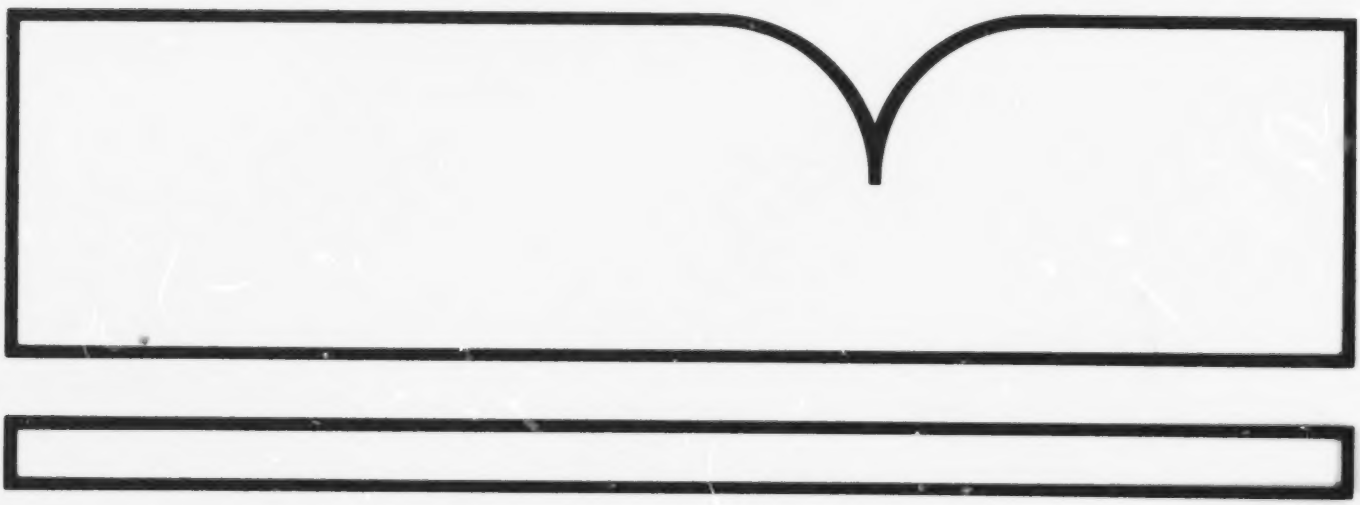

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16. ABSTRACT

The primary objective of this document is to evaluate the affordability and economic impact of additional control measures deemed necessary for a smelter-refinery to meet the lead emission standard. The emphasis in the analysis is on the impact of control costs on the smelter-refinery's profitability. The analysis was performed using control cost data from two different lead smelter studies in conjunction with other existing industry data.

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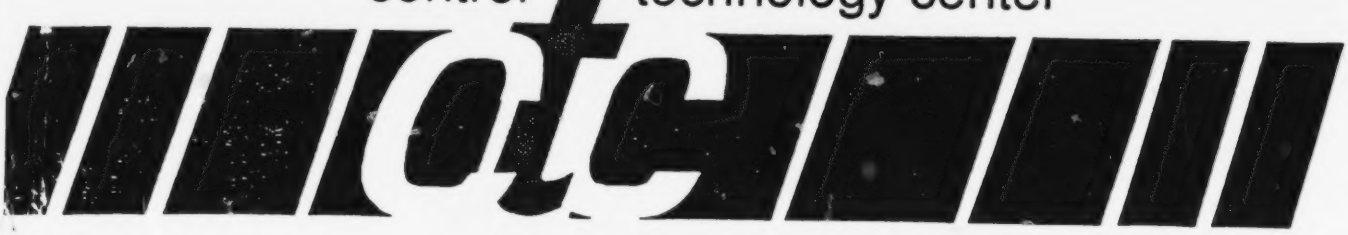

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CONTROL TECHNOLOGY CENTER

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PREFACE

This project was funded by EPA's Control Technology Center (CTC) in response to a request for assistance from EPA Regional Office VII.

The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) to provide technical assistance to State and Local air pollution control agencies. Three levels of assistance can be accessed through the CTC. First, a CTC HOTLINE has been established to provide telephone assistance on matters relating to air pollution control technology. Second, more in-depth engineering assistance can be provided when appropriate. Third, the CTC can provide technical guidance through publication of technical guidance documents, development of personal computer software, and presentation of workshops on control technology matters.

Engineering assistance projects such as this one focus on specific problems or concerns that are identified through contact with State and Local agencies. In this case, the CTC became involved as a result of a request by EPA Region VII to evaluate the affordability and economic impact of additional control measures deemed necessary for a smelter–refinery to meet the lead emissions standard. The emphasis in the analysis is on the impact of control costs on the smelter–refinery's profitability. The analysis was performed using control cost data from two different lead smelter studies in conjunction with existing firm and industry data.

Introduction

This report examines the economic impacts of EPA's ambient air lead standard of 1.5 $\mu g/m^3$ on The Doe Run Company primary lead smelter-refinery in Herculaneum, Missouri. The Herculaneum facility is currently not in compliance with the standard.

The economic impacts of the lead standard are evaluated in this report by assessing whether Herculaneum can afford to invest in pollution controls. The report begins with background information on Herculaneum and the U.S. primary lead industry. Then, two alternative representations of the costs necessary for Herculaneum to achieve compliance with the lead standard are presented. Next, the impact of the control costs on Herculaneum's profitability is evaluated. This will depend on the extent to which compliance costs must be absorbed. Lead is an internationally-traded commodity whose price is determined by global market factors. In a global context, the lead market is competitive, and Herculaneum acts as a price taker. Therefore, it is recognized that Herculaneum will not be able to recover compliance costs by increasing prices. However, because Herculaneum and its mines are interdependent, Herculaneum may be able to pass some of its compliance costs back to the mines. Finally, the ability of Herculaneum to finance the initial capital outlay required for compliance is examined.

Background

The Doe Run Co. lead smelter-refinery at Herculaneum, Missouri is the largest primary lead production facility in the U.S., with an annual capacity of 225,000 short tons (204,117 metric tons) of refined lead. In 1988, Herculaneum produced at capacity, with refined lead output of 225,403 short tons (204,482 metric tons).[1] In comparison, total industry output of primary refined lead in 1988 was 380,000 metric tons.[2] In 1987, total output of primary refined lead in the U.S. was 373,610 metric tons. This accounted for almost 12 percent of total world output of 3,176,600 metric tons.[3] Lead is also produced from secondary sources. In 1988, total secondary lead production in the U.S. was 635,000 metric tons.[4] 570,000

metric tons, or 90 percent, of secondary production in 1988 came from scrap batteries.

For most of 1988, only four primary lead smelters and/or refineries were in operation in the United States. ASARCO Inc. operated a smelter-refinery in Glover, Missouri; a smelter in E. Helena, Montana; and a refinery in Omaha, Nebraska. The fourth operation was Doe Run's Herculaneum smelter-refinery. Combined, these operations have capacity to produce 468,000 metric tons of refined lead annually.[5] In late 1988, Doe Run reopened parts of its smelter-refinery in Buick, Missouri, adding 127,000 metric tons to domestic refined lead capacity. This brought total domestic capacity for refined lead to 595,000 metric tons.

In 1981, annual domestic refined lead capacity was 715,000 metric tons. Capacity declined, however, as a result of the closure at the end of 1981 of Bunker Hill's smelter-refinery in Kellogg, Idaho. In addition, ASARCO has since closed its smelter in El Paso, Texas. The domestic primary lead industry has retrenched in response to decreased lead consumption, worldwide overcapacity, low prices, and environmental regulations.[6] The decline in consumption can be attributed to a phase-down in the use of lead solder, lead-based paints, and lead-based gasoline antiknock additives. Whereas tetraethyl lead, a gasoline antiknock additive, once accounted for over 20 percent of lead demand, it accounted for only about 2 percent in 1988.[7] The phase-down is considered to be complete, and demand has stabilized. Long-term demand growth of 1-2 percent per year is projected, in part from new battery applications.[8]

The Doe Run Co. was formed in November 1986 when St. Joe Minerals Corp., a subsidiary of Fluor Corp., and Homestake Mining Co. combined their lead mining, milling, and smelting-refining interests in Missouri. Fluor has a 57.5 percent interest in the partnership, while Homestake Mining is a 42.5 percent partner. In total, Doe Run owns six mines, four mills, and two smelter-refineries, and is the largest fully integrated producer of primary lead in North America. In addition to the 204,482 metric tons produced at Herculaneum in 1988, Doe Run produced 9,525 metric tons of refined lead at its Buick smelter-refinery. The combined annual capacity of Herculaneum and Buick is approximately 331,000 metric tons of refined lead.[9]

Doe Run's operations are all in Missouri's lead belt in the southeastern part of the state. The Missouri lead belt is the source of the majority of primary lead output in the U.S. Of nationwide recoverable lead mine output of 384,607 metric tons in 1988, Missouri accounted for 353,329 metric tons, or 92 percent.[10]

Although primarily a lead producer, Doe Run also produces copper and zinc concentrates. In 1988, Doe Run produced 77,175 metric tons of copper concentrate and 42,109 metric tons of zinc concentrate.[11] The company's proven reserves of 73.7 million short tons (66.9 million metric tons) of ore as of December 31, 1988 are 5.1 percent lead, 0.9 percent zinc, and 0.3 percent copper.[12]

Doe Run currently complies with EPA's SO_2 emissions standard and OSHA's lead blood-level standard. In addition to the lead emissions standard, Doe Run faces a host of other environmental, safety and health regulations that could significantly add to its control costs. These include the possibility that EPA will establish stricter standards for lead and SO_2 emissions, and that surface impoundment solids at lead smelters will be regulated as hazardous waste under the Resource, Conservation and Recovery Act (RCRA). Doe Run also faces the prospect of having to meet OSHA's limit for occupational exposure to airborne lead by 1991. Finally, the new EPA standard for lead in drinking water could result in increased costs to control contamination of local ground water and to control effluent discharges.

Doe Run is currently investing in a secondary lead production facility, to be located at the Buick site. The plant will add 60,000 short tons (56,261 metric tons) to the company's annual lead production capacity. Start-up is targeted for mid-1990, and the capital cost of the plant is estimated to be $34 million.[13]

Control Costs

Two alternative estimates are available of the cost of controls for Herculaneum to comply with the current lead emissions standard.

The first estimate is derived from a study of lead emission controls at Herculaneum conducted in April 1989 by Fluor Daniel, Inc., a unit of Fluor Corp., one of the parent companies of Doe Run.[14] Based on Fluor Daniel's study, it is estimated that the capital cost of controls is $7.7 million. The study does not assume any annual operating and maintenance costs, possibly because new control equipment would replace existing equipment. Consequently, annualized compliance costs consist only of annualized capital. Capital can be annualized through use of the Capital Recovery Factor (CRF), which expresses a capital asset as an annuity over its useful life:

$$CRF = \frac{i(1+i)^n}{(1+i)^n-1}$$

where,

i = the discount rate

n = years of useful life

Using a 15-year useful life and a 15 percent discount rate, the annualized compliance cost is calculated to be $1.3 million.

The alternative compliance cost estimate is offered in Bureau of Mines (BOM) Information Circular 9160, published in 1987 under the title "Lead Reduction in Ambient Air: Technical Feasibility and Cost Analysis at Domestic Primary Lead Smelters and Refineries."[15] The BOM estimated that Herculaneum would have to invest $62.8 million to control lead emissions. Annual costs of operating the new equipment would be $3.4 million. The BOM's estimates are in 1985 dollars. The costs can be adjusted to First Quarter 1989 dollars -- for comparability with the Fluor Daniel estimate -- by inflating by 8.8 percent, the change in the Chemical Engineering Plant Cost Index from 1985 to March 1989. In 1989 dollars, the BOM capital cost is $68.3 million, and the operating cost is $3.7 million. The annualized capital cost, again calculated using a useful life of 15 years and a discount rate of 15 percent, is $13.1 million. The total annualized cost is therefore $16.8 million.

The two estimates are widely disparate. On a per-pound basis, the Fluor Daniel annualized cost is 0.3 cents, while the BOM annualized cost is 3.7 cents. There are two main reasons for the disparity.

First, the BOM estimate is based on reducing lead emissions to the lowest level theoretically achievable. This may exceed what is necessary to meet the current lead standard. Thus, the BOM estimate may be overstated. Information in the Fluor Daniel report on emissions reductions is largely qualitative. Consequently, it is not possible to quantify the emissions reduction that Fluor Daniel expects to be able to achieve. Presumably, it will reduce lead emissions to the current standard, though such a claim is not made.

Secondly, the Fluor Daniel and BOM estimates are based on entirely different prescriptions for what is necessary to reduce lead emissions. The supposition in the Fluor Daniel estimate is that Best Available Control Technology (BACT) is currently not in place, and that necessary reductions in lead emissions can be achieved by improving the efficiency of controls on point sources of emissions, and by improving housekeeping and making minor process and equipment changes. Fluor Daniel estimated capital costs using internal company factors that were not specified; therefore, it is not possible to judge the accuracy of their method. The BOM, on the other hand, stipulates that point sources are already controlled with BACT, and that lead emissions can only be reduced by controlling fugitive emissions sources. This would entail enclosing the operation, installing new baghouses, and adding workplace controls for exposures to emissions that would be contained by an enclosure. The BOM estimated capital costs by factoring direct materials, labor, and construction equipment usage costs. This method is probably accurate to $\pm$30 percent.

It is not known which of the two cost estimates more accurately reflects the changes required to bring Herculaneum into compliance with the lead standard. It is possible that the true cost lies somewhere between the two estimates. Therefore, in this report, the economic impacts of both control costs will be examined.

Revenue

As a first step in assessing the affordability of pollution controls, Herculaneum's revenue must be estimated. Doe Run had total sales in 1988 of $230 million.[16] However, as mentioned, Doe Run operates six mines, four mills, and another smelter-refinery, in addition to Herculaneum. It is necessary to isolate Herculaneum's revenue contribution.

Lead output at Herculaneum in 1988 was 204,482 metric tons. This can be used as an estimate of future annual output. The average realized price of Herculaneum's output in 1988 is not known. On July 24, 1989, Doe Run increased its list price for lead from 40 cents to 42 cents per pound.[17] At the same time, however, the London Metal Exchange (LME) cash value for lead was only 32.1 cents per pound.[18] Typically, North American producers allow a discount off of their list price. A good estimate of the net price is the LME cash value plus an allowance of about 5 cents per pound for shipping costs.[19] This implies a current net price of about 37 cents per pound. This is consistent with the comment of a battery producer (batteries accounted for 76 percent of lead consumption in the U.S. in 1987) that discounts in the last week of July were "running over 10 percent off the 42 cent list price."[20]

The current net price of 37¢/lb can serve as an estimate of the future price of lead. Commodity prices are notoriously volatile, however. Table 1 lists average annual North American producer list prices from 1970 to 1988.[21,22] Since 1980, the average annual North American producer price has ranged from a high of 42.4¢/lb in 1980 to a low of 19.1¢/lb in 1985. As mentioned, Doe Run's list price is currently 42¢/lb. Clearly, the current price of lead is high by standards of the past couple decades. At the moment, the lead market is strong, in part because battery producers are replenishing inventories that fell to lower levels than expected over the winter.[23] If this is temporary, the price of lead could fall in the future. To account for uncertainty in the price of lead, two sensitivities will be examined: 27¢/lb and 47¢/lb. It is particularly important to examine the downside sensitivity -- 27¢/lb -- because of the current high price of lead.

Table 1

AVERAGE ANNUAL NORTH AMERICAN
PRODUCER LIST PRICE OF LEAD, 1970-1988

Year	Price (¢/lb)
1970	15.7
1971	13.9
1972	15.0
1973	16.3
1974	22.5
1975	21.5
1976	23.1
1977	30.7
1978	33.7
1979	52.7
1980	42.4
1981	36.5
1982	25.5
1983	21.7
1984	25.6
1985	19.1
1986	22.0
1987	35.9
1988	37.1

Source: References 21, 22.

At 37¢/lb, Herculaneum's revenue is calculated to be $166.8 million. Revenue is $121.7 million at 27¢/lb and $211.9 million at 47¢/lb. It is conceivable that Herculaneum also derives revenue from byproducts such as zinc, copper, and silver. In Homestake Mining's 1988 annual report, production of zinc and copper concentrates are specifically mentioned. However, these are mill products. No mention is made in the annual report of smelting byproducts. Therefore, it is conservatively assumed that Herculaneum's revenue derives solely from the sale of refined lead.

Profitability

Lead is an internationally-traded commodity whose price is determined by global market factors. In a global context, the lead market is competitive, and domestic producers are price takers. They are constrained to set prices that are in line with the international exchange price, relative tariffs and quotas, and transportation cost differentials. Already, 15 percent of domestic lead consumption is accounted for by imported lead metal and lead refined domestically from imported concentrates.[24] Therefore, it is unlikely that Herculaneum would be able to recover compliance costs through a price increase.

On the other hand, it may be possible for Herculaneum to pass some of its compliance costs back to its mines. This is because Herculaneum and the mines are interdependent. The mines supply concentrate to Herculaneum, while Herculaneum serves as a smelting and refining outlet for the mines. If, in the extreme, compliance costs were to prove to be prohibitive and Herculaneum were shut down, the mines would have to find an alternative smelting and refining outlet. Perhaps Buick has spare capacity, but, in general, U.S. lead smelting and refining capacity is limited. It might therefore be necessary for the mines to ship their concentrate overseas for smelting and refining. As mentioned previously, the transportation cost differential relative to the LME cash price is about 5 cents per pound. To avoid an increase in transportation and marketing costs, the mines might be willing to help absorb some of Herculaneum's compliance costs.

The extent to which the mines would be willing to share the burden of Herculaneum's compliance costs is not known. The maximum impact on

Herculaneum is represented by the case of full-cost absorption. In the analysis that follows, this case will first be examined. In order to examine this case, profitability at Herculaneum must be isolated. This is equivalent to evaluating Herculaneum as a profit center. Later, Herculaneum's interdependence with its mines will be recognized by considering the possibility that compliance costs can be passed backward to the mines.

Because it is privately held (by Fluor and Homestake Mining), Doe Run does not report its earnings to the public. Both Fluor and Homestake Mining disclosed some results of Doe Run's operations in their 1988 annual reports, however. Strangely, the disclosures are contradictory. Homestake Mining reported that Doe Run had operating earnings (before interest and taxes, which are paid at the corporate -- i.e., Fluor and Homestake Mining -- level, and perhaps some corporate overhead allocations) of $63.4 million on sales of $230.2 million in 1988, and operating earnings of $24.7 million on sales of $174.4 million in 1987. Of the $63.4 million in operating earnings in 1988, Homestake Mining reported its share as $29.8 million (not exactly 42.5 percent because of an adjustment made for assets contributed by the company to the partnership in excess of its equity share). This leaves $33.6 million for Fluor. However, Fluor reported its share of Doe Run's operating earnings in 1988 as $29.0 million. Fluor also reported that its share of 1988 sales was $123.5 million. For 1987, Fluor reported that Doe Run contributed $93.1 million to its sales and a net operating loss of $5.5 million to its earnings. The operating margin in 1988 was 27.5 percent as reported by Homestake Mining, and 23.5 percent as reported by Fluor. Despite the differences, both Homestake Mining and Fluor attributed the improved earnings in 1988 to higher volume, lower operating costs, and higher prices for lead and byproducts.

Since the figures reported by Fluor and Homestake Mining are for the entire Doe Run Co., they can only be used as guidelines for profitability at Herculaneum. To estimate Herculaneum's profitability, the aid of the Bureau of Mines' Minerals Availability Field Office in Denver, Colorado was enlisted. The BOM field office furnished estimates of capital and operating costs for a generic smelter similar to Herculaneum. In addition, the terms of a recent (1988) lead concentrate contract between a custom

smelter and mine in North America were provided. This can be used to estimate the cost to Herculaneum of lead concentrate.

Of course, Herculaneum does not purchase lead concentrate on the open market. Instead, lead concentrate is supplied by Doe Run's mines. In order to isolate Herculaneum's profitability, however, it is necessary to determine the market value of the lead concentrate supplied by the mines. The true economic cost to Herculaneum of lead concentrate is the market rate. Conversely, there is an opportunity cost to the mines if lead concentrate is transferred to Herculaneum at less than the market rate.

Specifications of the lead concentrate contract formula supplied by the BOM field office and an example of a raw materials cost calculation are provided in Exhibit 1. The contract was executed in 1988 between a custom smelter and mine in North America. Unlike the cost data supplied by the BOM field office, the lead concentrate contract is not necessarily generic. Contracts are negotiated individually between mines and smelters, and terms can vary considerably according to a number of different factors. In addition, not all concentrates are suitable for all smelters. Therefore, the contract formula should be considered as allowing for only a crude estimate of Herculaneum's raw materials costs.

In Exhibit 1, only the lead content is considered in calculating the cost of concentrate. It is possible that Herculaneum produces small amounts of zinc, copper, and silver as byproducts. However, neither Fluor nor Homestake Mining mentioned byproducts in discussing smelting-refining operations in its 1988 annual report. Morever, the BOM field office indicated that, in general, byproducts do not contribute significantly to profits at smelters. For example, profits from silver, which can be appreciable, tend to accrue to the mine. Therefore, excluding byproducts from both revenue and costs should have little impact on profits. Nevertheless, to the extent that byproducts contribute to Herculaneum's profits, profitability in this analysis will be understated.

Continuing with Exhibit 1, note that the cost of lead concentrate is equal to the concentrate's lead value, minus the cost to smelt and refine the concentrate (treatment charge), and minus a price participation clause which establishes how the value of lead in concentrate in excess of smelting and refining costs is shared between the smelter and the mine.

Exhibit 1

CONTRACT FORMULA FOR THE COST OF CONCENTRATE
(LEAD CONTENT ONLY)[a]

Inputs

(1) Lead content of concentrate = 75%

(2) Lead recovery rate = 95%

(3) Grade deduction = 1.5 units

(4) Percent paid for = (75-1.5)/75 x .95 = 93.1%

(5) Refined lead output = 204,482 metric tons

(6) Concentrate purchased = 204,482 metric tons ÷ 0.75 ÷ 0.95 = 286,992 metric tons

(7) Treatment charge rate (includes refining charge) = $180/metric ton

(8) Variable component of price participation agreement: 1/4¢ for every cent per pound in price of lead above 33¢/lb

(9) Fixed component of price participation agreement: 12¢/lb

Calculation for a lead price of 37¢/lb

(1) Value of lead content =
286,992 metric tons x 0.931 x 0.75 x $0.37/lb x 2,204.62 lbs/metric ton = $163.5 million

(2) Treatment charge =
$180/metric ton x 286,992 metric tons = $51.7 million

(3) Price participation = $[\$0.12/lb + [(37¢/lb - 33¢/lb) \times \frac{\$0.0025}{¢/lb}]] \times$
204,482 metric tons x 2,204.62 lbs/metric ton = $58.6 million

(4) Net paid to mine (cost of concentrate) =
$163.5 million - $51.7 million - $58.6 million = $53.2 million

[a]Based on an actual North American lead concentrate contract in 1988.

At a lead price of 37¢/lb, the value of the lead content is $163.5 million and the treatment charge is $51.7 million. The difference, $111.5 million, is divided between the smelter and the mine, with the smelter keeping $58.6 million (price participation = $58.6 million) and the mine receiving $53.2 million. The $53.2 million paid to the mine is the smelter's cost of lead concentrate. The results of the calculations in Exhibit 1 for a lead price of 37¢/lb are summarized in Table 2. The calculations of Herculaneum's materials cost using the lead concentrate contract formula for the lead price sensitivities of 27¢/lb and 47¢/lb are also presented in Table 2.

Net income before taxes at Herculaneum is calculated in Tables 3a and 3b. Table 3b expresses Table 3a on a per-pound basis. Net income before taxes is the appropriate measure of income for comparison with compliance costs because compliance costs are also before taxes. Net income before taxes is derived by deducting materials cost, operating cost, the cost of capital recovery, a return on capital factor, and corporate overhead from revenue.

Note that revenue in Table 3a is slightly higher than the value of lead content in Table 2. The difference is explained by the lead concentrate grade deduction of 1.5 units, listed as input number (3) in Exhibit 1. In input (4) in Exhibit 1, the grade deduction results in a factor of 73.5 ÷ 75, which is multiplied by the lead recovery rate. It is the ratio 73.5/75 that accounts for the difference between lead revenue and the value of lead in concentrate.

The operating and capital costs in Tables 3a and 3b are derived from calculations made by the BOM field office from its lead smelter cost model. The model was constructed for a generic smelter with specifications similar to Herculaneum (capacity, lead content in ore, etc.). The BOM cost calculations were in 1984 dollars. To adjust to 1989 dollars, the costs were increased by 10.2 percent, the change in the Chemical Engineering Plant Cost Index from 1984 to June 1989.

The operating cost of 11.3¢/lb is similar to an average smelting-refining operating cost estimate of 11¢/lb in 1981 dollars made by BOM in a previous study.[25]

Table 2

CALCULATION OF MATERIALS COST
($ Million)

	Price		
	27¢/lb	37¢/lb	47¢/lb
Value of lead content	$119.3	$163.5	$207.6
Treatment charge	51.7	51.7	51.7
Price participation	54.1	58.6	69.9
Net paid to mines[a] (cost of concentrate)	13.5	53.2	86.0

[a]Equal to the value of lead content minus the treatment charge and minus price participation.

Table 3a

ESTIMATE OF NET INCOME BEFORE TAXES
FROM LEAD PRODUCTION AT HERCULANEUM
(Millions of Dollars)

	Price		
	27¢/lb	37¢/lb	47¢/lb
Revenue	$121.7	$166.8	$211.9
Materials cost[a]	13.5	53.2	86.0
Operating cost[b]	50.8	50.8	50.8
Capital recovery[c]	9.1	9.1	9.1
Return on capital[d]	14.1	14.1	14.1
Corporate overhead	13.5	13.5	13.5
Net income before taxes	20.7	26.1	38.4
Before-tax profit margin	17.0%	15.6%	18.1%

[a]Calculated using the lead concentrate contract formula in Exhibit I.

[b]Includes operating and maintenance costs, current environmental compliance costs, and costs of administration and supervision.

[c]Annual value of the capital cost ($135.8 million) amortized evenly over 15 years.

[d]Annual value required to earn a 15 percent return on capital (i.e., to pay for a 15 percent cost of capital).

Table 3b

ESTIMATE OF NET INCOME BEFORE TAXES
FROM LEAD PRODUCTION AT HERCULANEUM
(Cents per Pound[a])

	Price		
	27¢/lb	37¢/lb	47¢/lb
Revenue	27.0¢	37.0¢	47.0¢
Materials cost[b]	3.0	11.8	19.1
Operating cost[c]	11.3	11.3	11.3
Capital recovery[d]	2.0	2.0	2.0
Return on capital[e]	3.1	3.1	3.1
Corporate overhead	3.0	3.0	3.0
Net income before taxes	4.6	5.8	8.5

[a]Based on 1988 production at Herculaneum of 450,806,000 lbs.

[b]Calculated using the lead concentrate contract formula in Exhibit I.

[c]Includes operating and maintenance costs, current environmental compliance costs, and costs of administration and supervision.

[d]Annual value of the capital cost ($135.8 million) amortized evenly over 15 years.

[e]Annual value required to earn a 15 percent return on capital (i.e., to pay for a 15 percent cost of capital).

Capital recovery is simply the annual value of the capital cost, $135.8 million, amortized evenly (straight-line depreciation) over an assumed useful life of 15 years. The $135.8 million capital cost is for a new facility that, like Herculaneum, is not in compliance with the lead standard, but is in compliance with existing particulate and SO_2 standards.

A firm will also require a return to cover its cost of capital. To finance an investment, a firm can use some combination of debt and equity. In Tables 3a and 3b, the cost of capital is assumed to be 15 percent. In order to pay for a cost of capital of 15 percent, a firm needs to earn a 15 percent return on investment. The average annual amount required to earn a 15 percent return on capital is calculated to be $14.1 million, or 3.1¢/lb. The calculation is simply the difference between the annualized capital cost, calculated using the Capital Recovery Factor over a useful life of 15 years at a discount rate of 15 percent, and the annual value of the capital cost amortized evenly over 15 years. Since Tables 3a and 3b account for the cost of capital, net income is net of interest expense. However, considering that interest rates are currently less than 15 percent, return on capital in Tables 3a and 3b may overstate the cost of capital if the investment can be financed largely or entirely with debt. Therefore, the net income estimate may be conservative -- in the short run. In the long run, a firm must cover its total cost of capital. Fifteen percent is believed to be a reasonable estimate of the total cost of capital, consisting of a mix of debt and equity.

The corporate overhead factor of 3.0¢/lb is from a previous BOM study in 1988.[26] This factor accounts for overhead such as selling and administrative expenses. In the BOM study, the corporate overhead factor was described as including transportation costs to the consumer.

The before-tax profit margin at 37¢/lb, the current price of lead, is lower than the operating margins reported by Fluor and Homestake Mining for Doe Run in 1988, 23.5 percent and 27.5 percent, respectively. However, the Fluor and Homestake operating margins do not account for interest expense and corporate overhead. Therefore, the net income calculation in Tables 3a and 3b appears to be reasonable.

As a sensitivity, net income is recalculated in Table 4 for a lead price of 27¢/lb using a different materials cost. The price participation

Table 4

ESTIMATE OF NET INCOME BEFORE TAXES
AT A PRICE OF 27¢/LB: MATERIALS COST SENSITIVITY

	$ Million	¢/lb[a]
Revenue	$121.7	27.0¢
Materials cost[b]	33.8	7.5
Operating cost[c]	50.8	11.3
Capital recovery[d]	9.1	2.0
Return on capital[e]	14.1	3.1
Corporate overhead	13.5	3.0
Net income before taxes	0.4	0.1
Before-tax profit margin	0.3%	0.3%

[a]Based on 1988 production at Herculaneum of 450,806,000 lbs.

[b]Equal to one-half of the difference at a lead price of 27¢/lb between the value of lead content, $119.3 million, and the treatment charge, $51.7 million.

[c]Includes operating and maintenance costs, current environmental compliance costs, and costs of administration and supervision.

[d]Annual value of the capital cost ($135.8 million) amortized evenly over 15 years.

[e]Annual value required to earn a 15 percent return on capital (i.e., to pay for a 15 percent cost of capital).

clause in the concentrate contract included a variable component for prices of lead exceeding 33¢/lb. It is possible that the contract formula is not applicable at prices below 33¢/lb, and that at 27¢/lb, the contract would be renegotiated. This is suggested by the change in the distribution of the value of lead content in excess of the treatment charge at different lead prices in Table 2. Note that at a lead price of 47¢/lb, price participation for the smelter is $69.9 million, while the mines are paid $86.0 million. At 37¢/lb, the smelter keeps $58.6 million, while the mines receive $53.2. At 27¢/lb, however, while the smelter keeps $54.1 million, the mines receive only $13.5 million. The reason for this is that the lead concentrate contract is formulated so that at lead prices below 33¢/lb, all of the decrease in lead profits resulting from a decline in the price of lead flows back to the mines. In other words, the contract formula discriminates against the mines at lead prices below 33¢/lb.

It is not known how lead profits would be shared by smelters and mines at lead prices below 33¢/lb. For the sensitivity in Table 4, it is assumed that the difference between the value of lead content, $119.3 million, and the treatment charge, $51.7 million, is shared equally by the smelter and the mines. The smelter's price participation is $33.8 million, and, as indicated in Table 4, the smelter's materials cost (the mines' payment) is also $33.8 million. As a result of the increase in materials cost from $13.5 million to $33.8 million, Herculaneum's net income declines to $400,000 or 0.1¢/lb, just barely above break-even.

Affordability of Annualized Costs

Tables 5a and 5b show the effect on Herculaneum if annualized compliance costs are fully absorbed. At the current lead price of 37¢/lb, net income before taxes would be 5.5¢/lb after absorption of the Fluor Daniel compliance cost, and 2.1¢/lb after absorption of the BOM compliance cost. If the price of lead were to fall to 27¢/lb, net income would be either 4.3¢/lb or 0.9¢/lb under the two compliance cost scenarios.

The effect of the Fluor Daniel compliance cost is rather minimal. The effect of the BOM compliance cost is more severe, but it is still affordable. Under all price scenarios, Herculaneum would continue to be

Table 5a

POST-COMPLIANCE NET INCOME BEFORE TAXES
AT HERCULANEUM
(Millions of Dollars)

	Compliance Cost$_1$[a]			Compliance Cost$_2$[b]		
	P=27¢/lb	P=37¢/lb	P=47¢/lb	P=27¢/lb	P=37¢/lb	P=47¢/lb
Pre-compliance net income before taxes	$20.7	$26.1	$38.4	$20.7	$26.1	$38.4
Annualized compliance cost	1.3	1.3	1.3	16.8	16.8	16.8
Post-compliance net income before taxes	19.4	24.8	37.1	3.9	9.3	21.6

[a]The Fluor Daniel capital cost estimate of $7.7 million, or $1.3 million annualized.

[b]The BOM capital cost estimate of $68.3 million and annual operating cost estimate of $3.7 million, for a total annualized cost of $16.8 million.

Table 5b

POST-COMPLIANCE NET INCOME BEFORE TAXES
AT HERCULANEUM
(Cents per Pound[a])

	Compliance Cost$_1$[b]			Compliance Cost$_2$[c]		
	P=27¢/lb	P=37¢/lb	P=47¢/lb	P=27¢/lb	P=37¢/lb	P=47¢/lb
Pre-compliance net income before taxes	4.6¢	5.8¢	8.5¢	4.6¢	5.8¢	8.5¢
Annualized compliance cost	0.3	0.3	0.3	3.7	3.7	3.7
Post-compliance net income before taxes	4.3	5.5	8.2	0.9	2.1	4.8

[a]Based on 1988 production at Herculaneum of 450,806,000 lbs.

[b]The Fluor Daniel capital cost estimate of $7.7 million, or $1.3 million annualized.

[c]The BOM capital cost estimate of $68.3 million and annual operating cost estimate of $3.7 million, for a total annualized cost of $16.8 million.

profitable after compliance costs. In the short run, Herculaneum could continue to operate because it would be covering operating and materials costs, its variable production costs. Herculaneum could also continue to operate in the long run. In the long run, all costs are variable, including capital recovery (in the long run a firm can change plant capacity or move to another industry), the cost of capital, and overhead. As Tables 5a and 5b demonstrate, these costs would also be covered. Post-compliance net income, representing net income in the long term, is greater than zero under each lead price scenario: 0.9¢/lb at a lead price of 27¢/lb, 2.1¢/lb at a lead price of 37¢/lb, and 4.8¢/lb at a lead price of 47¢/lb.

The BOM considers a 15 percent internal rate of return (IRR) as necessary for a mineral operation to continue producing over the long term.[27] A 15 percent IRR has already been built into the calculation of post-compliance net income through the requirement of a 15 percent return on capital in Tables 3a and 3b and the calculation of the annualized compliance cost in Tables 5a and 5b using a 15 percent discount rate. Therefore, so long as post-compliance net income is greater than zero, Herculaneum will be covering its cost of capital by earning a 15 percent IRR and will be making a profit over the long term.

The effects on net income of the materials cost sensitivity introduced in Table 4 are examined in Table 6. The sensitivity assumes that lead profits are shared equally by mines and smelters at lead prices below 33¢/lb and that the price of lead falls by 10¢/lb to 27¢/lb. Under both compliance cost scenarios, net income would become negative. It would be possible for Herculaneum to continue operating in the short run, but in the long run it would be better for Doe Run to shut down Herculaneum and redeploy its assets to a more profitable venture (i.e., one that earns a 15 percent return on investment).

If Herculaneum were closed, domestic primary refined lead capacity would decline by 34 percent. As a result, it would probably be necessary for the U.S. to export much of its lead ore and concentrate, and the U.S. would probably have to increase its reliance on foreign sources of lead metal, though perhaps the slack could be picked up somewhat by domestic secondary producers. The employment impact is not known, but it could be

Table 6

POST-COMPLIANCE NET INCOME BEFORE TAXES
AT A PRICE OF 27¢/LB: MATERIALS COST SENSITIVITY

	Compliance $Cost_1$[a]		Compliance $Cost_2$[b]	
	$ Million	¢/lb[c]	$ Million	¢/lb[c]
Pre-compliance net income before taxes	$0.4	0.1¢	$ 0.4	0.1¢
Annualized compliance cost	1.3	0.3	16.8	3.7
Post-compliance net income before taxes	(0.9)	(0.2)	(16.4)	(3.6)

[a]The Fluor Daniel capital cost estimate of $7.7 million, or $1.3 million annualized.

[b]The BOM capital cost estimate of $68.3 million and annual operating cost estimate of $3.7 million, for a total annualized cost of $16.8 million.

[c]Based on 1988 production at Herculaneum of 450,806,000 lbs.

significant. Overall, Doe Run employed 1,036 workers at the end of 1988.[28] No doubt, many of these workers are employed at Herculaneum.

It should be noted that in addition to the impact of compliance costs on profitability, Doe Run would also consider the cost of shutting down Herculaneum in making a shutdown decision. To the extent that shutdown costs exceed salvage value, Doe Run may be willing to sustain small losses from operating Herculaneum in order to postpone a shutdown decision.

It is apparent that if the price of lead falls, Herculaneum's long-term viability is very sensitive to how lead profits are shared by mines and smelters. The lead concentrate contract used to calculate materials cost may not be applicable for lead prices below 33¢/lb. Additional research is needed to determine the comparative impact on the profitability of mines and smelters at lead prices below 33¢/lb.

To this point, Herculaneum's interdependence with its mines has not been considered. If, as discussed previously, Doe Run's mines would have an economic incentive to help share Herculaneum's compliance cost burden, the economic impact on Herculaneum would be less severe. In the compliance cost scenarios presented in Tables 5a and 5b, Herculaneum's long-term viability was already established. For the materials cost sensitivity in Table 6, however, the interdependence of Herculaneum and its mines could influence Doe Run's decision whether or not to shut down Herculaneum. Already, under the sensitivity, Herculaneum is close to the shutdown point, as pre-compliance net income is only 0.1¢/lb. Therefore, Herculaneum's long-run survival would require that the mines absorb all of the compliance costs. If, in the event that Herculaneum were shut down, the mines were forced to export concentrate in order to stay in business, and marketing and transportation costs increased by, say, 5¢/lb, the mines might be willing to take on compliance costs of up to 3.7¢/lb (the BOM cost scenario). The mines' ability to absorb compliance costs would, of course, depend on their own profitability. Unfortunately, without knowledge of mine profitability and the specific options available to Doe Run's mines if Herculaneum were shut down, it is beyond the scope of this study to determine the extent to which the mines would be able to help absorb Herculaneum's compliance costs.

Capital Affordability

In addition to the ability to absorb annual compliance costs, it is necessary to examine the ability of Herculaneum to finance an initial capital outlay of from $7.7 million to $68.3 million. One source of financing is internal cash flow. By making the assumption that capital expenditures are offset by depreciation (constant asset base), net income is a proxy for cash flow. As Table 3a indicated, current (price of lead = 37¢/lb) net income at Herculaneum is $26.1 million. Therefore, Herculaneum would be able to finance 38 percent of the maximum capital cost of $68.3 million from net income in one year.

Debt could also be issued. At the end of 1988, Homestake Mining had long-term debt of $60.2 million compared to $757.0 million in shareholders' equity, while Fluor had long-term debt of $95.0 million and $601.7 million in shareholders' equity. Both companies have a low degree of financial leverage and should have plenty of capacity to take on additional debt.

Finally, both parent companies have liquid assets which could help finance the investment in pollution controls. At year-end 1988, Homestake Mining had $91.4 million and Fluor had $164.6 million in cash and cash equivalents. With regard to overall liquidity, Homestake Mining had working capital (current assets minus current liabilities) of $242.4 million at the end of 1988, while Fluor had working capital of $154.4 million.

Summary and Conclusions

Under current market conditions, the Doe Run Company primary lead smelter-refinery in Herculaneum, Missouri would be able to invest as much as $68.3 million in pollution controls to comply with EPA's lead emissions standard of 1.5 ug/m^3, and would still be profitable in the long run. Herculaneum would be able to cover its cost of capital by earning a 15 percent internal rate of return (IRR). Thus, the facility would be able to meet the Bureau of Mines' criterion of a 15 percent IRR as necessary for a mineral operation to continue producing over the long term. Herculaneum

would also be able to finance the initial capital outlay required for compliance.

In the long run, all costs are variable, and a firm can avail itself of such opportunities as changing plant capacity or moving to another industry. Under current market conditions, the imposition of control costs would not change Herculaneum's incentive to maintain current capacity and remain in the lead smelting-refining business. However, Doe Run may consider other options in order to avoid making the control expenditures, such as switching production to its Buick facility. The benefits of doing this would depend on Buick's comparative profitability, including the costs -- if any -- necessary to bring Buick into compliance with the lead standard. If the capital cost is a high as $68.3 million, Doe Run may also consider investing in a new smelting-refining facility instead of rehabilitating Herculaneum. The $68.3 capital cost represents slightly over half of the estimated cost of the current Herculaneum facility, $135.8 million. In a 1988 study, the Bureau of Mines found that it would be more cost-effective for lead producers in Missouri to invest, as a consortium, in a new flash smelter that would meet current environmental standards, than to rehabilitate existing plants.[29]

If current market conditions change, i.e., if the price of lead declines, the affordability of the controls would depend on the cost of lead concentrate. The contract formula used to calculate the cost of lead concentrate may not be applicable at lead prices below 33¢/lb. Applying the lead concentrate contract at a lead price of 27¢/lb, it was found that Herculaneum would still be profitable after absorbing compliance costs. Under the hypothetical scenario that lead profits would be shared equally by mines and smelters at a lead price of 27¢/lb, however, it was seen that Herculaneum's long-term viability could not be assured. It would be very useful to obtain additional information, perhaps from industry sources, on lead concentrate contracts for lead prices below 33¢/lb.

Even if the price of lead falls to 27¢/lb, and lead concentrate contracts are renegotiated to redistribute lead profits between mines and smelters, Herculaneum might not have to shut down if Doe Run's mines have a vested interest in Herculaneum's survival. Herculaneum and its mines are interdependent, and the mines may have an economic incentive to help absorb

some of Herculaneum's compliance costs. To the extent that Herculaneum's compliance costs can be passed backward to the mines, the economic impact on Herculaneum of the materials cost sensitivity at a lead price of 27¢/lb would be less severe.

Finally, two compliance cost estimates were examined that are widely disparate. One capital cost is only $7.7, while the other is $68.3 million. Although both are affordable, the higher cost would have a significant impact on Herculaneum's earnings. Perhaps additional research is needed to come up with a more definitive estimate of compliance costs.

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